

Concept of Operations (CONOPS) for Evaluation of Latent Fingerprint Technologies 2007 (ELFT07)

24 January 2007

1. Background and Objectives

The *National Institute of Standards and Technology (NIST)* is planning to conduct a series of tests for evaluating the state of the art in automated latent fingerprint matching. The intent of the testing is to quantify the core algorithmic capability of contemporary matchers. The testing will be conducted using a software-only implementation, and will utilize NIST hardware.

The initial round of tests is scheduled for the April 2007 timeframe. The scope and structure of these tests are based partly upon lessons learned from the April 2006 *NIST Latent Fingerprint Testing Workshop*, supplemented by technical interchanges with workshop participants and vendors. The umbrella project for the series of tests has been named *Evaluation of Latent Fingerprint Technologies (ELFTS)*.

EFTS is structured as a multi-year project. The first part of this project, ELFT07, consists of two tests, run in a "lights-out" environment, followed by a workshop. The two tests have been termed Phase I and II. Phase I is a *proof of concept test*, whose main purpose is to demonstrate integrity of the software in a lights-out environment. During Phase I the software will demonstrate: a) automated feature extraction from latent images; b) the ability to match these features against enrolled 10-print backgrounds; and c) generation of candidate lists. Phase II will then employ a larger database to quantify the achievable performance ("hit rate") for automated searches.

In subsequent years (2008+) the above tests will be expanded in a number of ways and directions. First we plan to augment the ten-print databases with a mix of rolled and plain impressions ("flats"). These will enhance our (and the community's) understanding of the challenges of matching latents against flats. Continuing this line of investigation, we will then transition to searches of *plain impressions against databases of latent images* (sometimes referred to as *reverse searches*). Initially these tests will be restricted to single-finger searches, and subsequently will be enlarged to multi-finger latent searches.

Additional follow-on tests envisioned might include: a) latents scanned at enhanced resolution (1000 and 2000 bpi); b) latents lifted/developed/processed in diverse manner; c) latents matched against latents; and d) searches employing new or non-traditional features (e.g., level-3 features). NIST is also looking into the development of *latent image quality measures*.

Of course the ultimate goal goes far beyond simply quantifying performance. We fully expect that understanding the performance envelope and limitations of contemporary matchers will lead to improvements in technology. In turn, this will lead to enhanced performance for searches of ten-prints and plain impressions against unsolved latent databases. An equally important objective is to provide law enforcement agencies with the capability to search their unsolved latent fingerprints with greatly reduced effort. However, the full impact of this work may not be felt for several years.

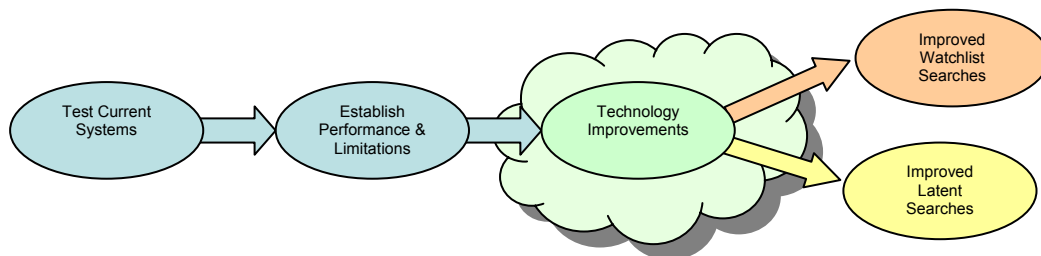


Figure 1 -- Overall Project Goals

We have outlined above with a “broad brush” the full scope of this project. In the remainder of this document we focus on this year’s portion of the project, ELFT07.

It will be recalled that ELFT07 consists of two tests, termed Phase I and II, followed by a workshop. A schematic for ELFT07 is shown below.

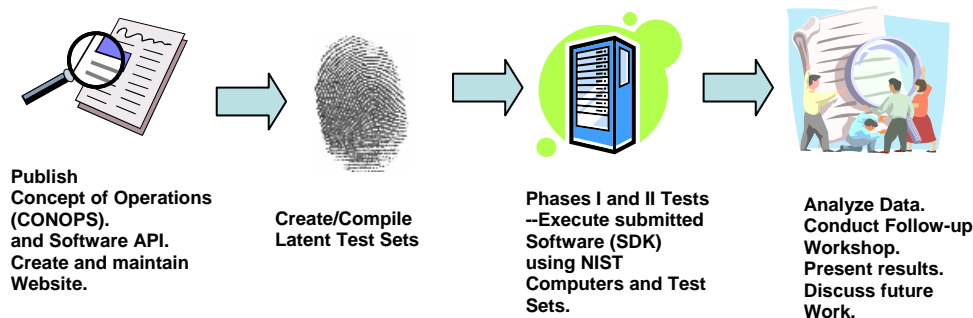


Figure 2 – Schematic of ELFT07

2. Who Should Participate?

Developers of latent fingerprint matcher software systems are strongly encouraged to participate in ELFT07. In addition, companies, research organizations, or universities that have developed mature prototypes, or stable research latent fingerprint matchers, are invited to participate. The latent fingerprint matching software submitted need not be “operational,” nor a “production” system, nor commercially available. However, the system must, at a minimum, be a stable implementation capable of being “wrapped” (formatted) in the API specification that *National Institute of Standards and Technology (NIST)* has published¹ for this evaluation. Anonymous

¹ The API is available at http://fingerprint.nist.gov/latent/elft07/elft07_api.pdf

participation will not be permitted. The Application form for participation is found on the NIST website. The Application form goes into further details regarding application and qualification.

3. Publication of Participation and Results

NIST understands that this project is entering a relatively unexplored field, and many challenges lie ahead. For this reason we have structured ELFT07 to include two phases. We consider Phase I to be a *Proof of Concept Test*. This means that the primary objective of Phase I will be to demonstrate that the submitted SDK executes on the Phase I data to completion in a lights-out environment, and produces a “meaningful” output. A “meaningful” output is basically an output in the correct format. The results of Phase I will be discussed with the Participant on a “one-on-one” basis, but will not be published or submitted to other government agencies. The number, but not the names, of participants who attempted and completed Phase I will be disclosed. Participants will have the option to withdraw anonymously following participation in Phase I. (This means that their withdrawal will not become a public announcement.)

Participants who elect to continue to Phase II may resubmit their SDKs. These need not be identical to those of Phase I. Following completion of Phase II testing the Government will combine all results into a Final Report. The *Evaluation of Latent Fingerprint Technologies Test, Phase II Final Report* will contain, at a minimum, descriptive information concerning ELFT07, descriptions of each experiment, and aggregate test results. By “aggregate test results” we mean that no specific candidate list or vendor-specific scores will be mentioned.

NIST will use DET performance metrics as the primary indicators of one-to-many identification search accuracy. This involves plotting false rejection versus false acceptance rates for all threshold values. NIST will also report enrollment and search timing information. NIST may compute and report other aggregate statistics.

Participants will have an opportunity to review and comment on the Final Report. Participants’ comments will be either incorporated into the main body of the report (if it is decided NIST reported in error) or published as an addendum. Comments will be attributed to the participant. After the release of the Phase II Final Report, Participants may decide to use the results for their own purposes. Such results shall be accompanied by the following phrase: “Results shown from the Evaluation of Latent Fingerprint Technologies Test (ELFT07) do not constitute endorsement of any particular system by the U. S. Government.” Such results shall also be accompanied by the Internet address (URL) of the ELFT07 Final Report on the ELFT07 website. Note that for Phase II and beyond NIST intends to publish statements of the performance of all implementations submitted for testing. These will include measurements of identification error rates and throughput. These results will be attributed to participants. Accordingly, NIST will require an appropriately signed application form from all participants and NIST will not evaluate any implementation unless the participant consents to the disclosure of its performance. The NIST test uses sequestered images. These will not be provided to participants.

4. Protection of Vendor’s Software

NIST recognizes the proprietary nature of the participant’s software and will take all reasonable steps to protect this. The software submitted will be in an executable

library (SDK) format, and no algorithmic details need be supplied. NIST will use the Participants SDK software only for the agreed-upon testing, and in the event errors are subsequently found, to rerun prior tests and resolve those errors. NIST agrees not to use the Participants software for purposes other than indicated above, without express permission by the Participant.

5 What is meant by “Lights-out”?

The term “lights-out,” as used in this document, will indicate that no human assistance will be required in conducting the latent searches. In particular, all feature extraction steps, both for the enrolled images and for the latent images, must be performed entirely by the SDK under test.

There are good reasons why NIST selected the “lights-out” mode of testing:

1. It decouples the skill of the human expert from the intrinsic merits of the software.
2. It protects the privacy of the test data, thereby allowing the use of *Sensitive but Unclassified Data*.
3. It encourages a longer term, progressive view for the performance envelope of latent matching software.
4. In the longer term, NIST envisages that automated search capabilities will assist latent experts by reducing the size of candidate lists that they need to examine. To achieve this may require additional computer processing beyond current practice in order to produce candidate lists restricted to candidates having a “high probability” of being a hit. We refer to this as candidate list reduction. We plan to implement candidate reduction as follows:

Each candidate on the list will be accompanied by two fields. The first contains the matching score. The second field contains an estimate of the probability that this candidate is a true match. The exact definition of this “probability” and its method of implementing this are left to the vendor. One obvious approach is a direct *score* → *probability* translation. However, very likely a more sophisticated approach would produce better results. (For example, the translation function might include: a) delta-score to next highest candidate, and b) quality of latent and its (purported) mate, and c) number of minutiae found in latent. These are mere suggestions and need not be followed.)

For the Phase I test candidate list reduction is not required. (The vendor could enter a 1.0 into the probability field for every candidate on the list.) For Phase II some type of candidate list reduction is preferred.

Although this is a “light-out” test NIST will use some human assistance in the data preparation phase. Any such assistance will be provided by NIST, and might include a) cropping and/or re-orienting of selected latent images, and b) specifying a region-of-interest in the form of a mask. The mask will be a byte image conformal with the size of the latent image. Initially only two values will be used for each pixel, 0 and 255. A zero value will indicate “do not use this pixel,” while 255 will indicate a “good” pixel. In the

future these two values may be augmented by other values to indicate finer gradations of quality. NIST will also involve latent experts for examining potential consolidations and for resolving contested or unclear results.

6. Test Objectives - What will be Tested during ELFT07?

As indicated above, the primary purpose the testing is to quantify the core algorithmic capability of contemporary matchers in order to understand their strengths and limitations. The testing will be conducted using a software-only implementation, in a lights out environment, and utilizing NIST hardware and datasets.

NIST will use DET performance metrics as the primary indicators of one-to-many identification search accuracy. This involves plotting false rejection versus false acceptance rates for all threshold values. NIST will also report enrollment and search timing information. NIST may compute and report other aggregate statistics, such as the number of “hits” in each position (first, second, third, etc.).

Speed of execution, for both enrollment and latent search is of secondary importance. However, in order to conduct these tests in a reasonable amount of time NIST must impose some limitations. These are covered in Section 8. NIST will caveat any timing measurements by noting that operational latent searching algorithms are likely to be implemented in more sophisticated hardware.

7. Test Data

NIST will select the test datasets from its internal sources. The Test Datasets are protected under the Privacy Act (5 U.S.C. 552a), and will be treated as *Sensitive but Unclassified* and/or *Law Enforcement Sensitive*. ELFT07 Participants will have no access to ELFT07 Test Data, either before, during or after the test, with the exception of the small Validation Dataset.

The Validation Dataset is a very small data set, nominally comprised of ten search latents and 100 background ten-prints. The purpose of this dataset is to demonstrate stable software compliant with the API. Upon receiving the vendor’s SDK NIST will rerun the vendor’s software using the Validation Dataset. Before the vendor is officially accepted (designated a *Participant*) NIST must be able to reproduce the vendor’s results.

In the event of disagreement in the two outputs, or other difficulties, the Participant will be notified. Participants will be notified with a detailed description of the problem(s) and given reasonable opportunity to resubmit.

Both Phase I and Phase II Test Datasets will consist of latent images for searches and ten-prints for the background (“gallery”). For both tests, but especially for Phase I, NIST will attempt to make the test set as “benign” as reasonable.

Latent images will be supplied uncompressed, and will have been scanned at either 500 ppi or 1000 ppi. The vendor should be prepared to handle either resolution. Additional image characteristics may be found in the API.

Background ("gallery") data will consist of rolled ten-print impressions, scanned at 500 ppi, and presented in a decompressed form.

The nominal sizes of the Phase I and Phase II Datasets are as follows:

ELFT07 Dataset Characteristics		
Dataset	Number of Latent Searches	Number of Ten-prints
Validation	10	100
Phase I	100	1000
Phase II	1000	5000

8. Testing Platform

NIST will host the vendor's software (SDK) on a high-end PC (workstation/server type). Although these PCs include a mix of models, a "typical" PC will have the equivalent of a Pentium 4, 2.8 GHz processor, or higher; 2 GB of memory; and at least 50 GB of disk memory. The vendor software must be able to reside and execute on this single PC. NIST, at its discretion, must be able to copy the software to several PCs to expedite or scale-up the testing. These computers are configured with either a Windows 2000 or Linux operating system.

9. Format of Vendor Software

Vendor software should be submitted to NIST via a Software Development Kit (SDK) library. The vendor may supply Windows 2000 or Linux implementations. The Application Programming Interface (API) specification provides further details regarding the format in which vendors must submit their software. See → <http://fingerprint.nist.gov/elft07>

Execution occurs in two passes:

1. Enrollment: The first phase consists of feature extraction of the background fingerprints. This process converts records into proprietary representations. The enrolled fingerprints will consist of rolled impressions of ten fingerprints. Not all latent search prints will have mates in this background. The output of this enrollment is entirely at the discretion of the vendor except that all data must be written into a single directory. The input images will not be latent fingerprints and latent fingerprint feature extraction algorithms are probably inappropriate at this stage
2. Matching: Each latent search image is matched against the enrolled data and a candidate list is generated. The searching process is unregulated, and the portion of the entire enrolled data is searched is entirely unregulated by the API. Vendors may invoke multi-stage algorithms within the top level search function call to NIST. Participating vendors will be supplied a "toy problem" to test their software before submitting it to NIST. Vendors must submit candidate lists from these problems to NIST. Once NIST has received vendor implementations it will rerun the test and check its candidate lists against those submitted. If a difference occurs, or if other problems are

encountered, the vendor will be required to respond to NIST requests for updated implementations.

NIST may provide a latent image with an accompanying region of interest. This shall be specified as a list of polygon points. The implementation should be able to perform searches with and without the mask. The implementation is free to ignore this information. The vendor's software should default to "no mask option" when no mask is supplied by NIST.

10. Timing Requirements

For ELFT07 NIST will allow the simultaneous submission of two SDKs, a primary and secondary. It is envisioned that the first (primary) SDK would be a "slow but accurate" version of the software, while the second would be a "fast and but less accurate." (However, these are suggestions, and need not be followed. The vendor may submit any two SDKs, subject to the timing restrictions below. The vendor need not supply any details regarding the differences between the two SDKs which might reveal proprietary information.)

Execution time is a concern. We require that vendors remain within the following limits:

Phases I and II Execution Time Limits	
Primary SDK	
Enrollment	Total Time (seconds) $\leq 150 * (\text{number of ten-prints in background})$
Search	Time per Search (seconds) $\leq 350 + 0.2 * (\text{number of ten-prints in background})$
Secondary SDK	
Enrollment	Total Time (seconds) $\leq 80 * (\text{number of ten-prints in background})$
Search	Time per Search (seconds) $\leq 250 + 0.1 * (\text{number of ten-prints in background})$

(Comments and questions should be submitted to the evaluation team at latent@nist.gov.)

11. Test Schedule

NIST has created a website to serve as the central repository for all information regarding NIST's latent fingerprint activity. The URL is ➔ <http://fingerprint.nist.gov/latent>. It links to the ELFT-07 testing ➔ [homepage](#) which contains:

1. Application form for ELFTS07
2. API specifications for vendors' implementations
3. This document (CONOPS)
4. Summary of NIST Latent Fingerprint Testing Workshop, and
5. A comment template.

The schedule is tabulated below. The later entries are subject to certain contingencies. However, NIST intends to adhere to the schedule as closely as possible.

ELFT07 Master Schedule			
#	Action	Actor	Date
1	Announcement of Latent Evaluation	NIST	2006-11-17
2	Publication of draft API and Latent Evaluation Concept Paper, and solicitation of comments	NIST	2006-11-17
3	Deadline for submission of comments on API and CONOPS to NIST. These should be submitted to latent@nist.gov	Participants	2006-12-22
4	Publication of API	NIST	2007-01 -26
5	Publication of Latent Evaluation Application Form	NIST	2007-01 -26
6	Deadline for submission to NIST of Latent Evaluation Application Form	Participants	2007-02-16
7	Publication of Validation Data	NIST	2007-02-23
8	Deadline for submission to NIST of written notice of withdrawal from test. Withdrawal after this time will be reported in NIST publications.		2007-03-30
9	Submission of SDK and Validation Dataset results	Participants	2007-03-30
10	Completion of SDK conformance testing and integration	NIST	2007-04-13
11	Commencement of Phase 1 test	NIST	2007-04-16
12	Completion of Phase 1 trial, and delivery of results to participants	NIST	2007-05-18
13	Announcement of schedule for submission Phase 2 SDK	NIST	2007-05-21
14	Submission of Phase 2 SDK (correct operation is assumed)	Participants	T
15	Completion of Phase 2 test	NIST	T+6 months
16	Publication of formal evaluation report	NIST	T+6 months
17	Workshop to summarize Phase 2 and plan subsequent phases	NIST	T+6 months

12. Supplemental Notes

The selection of the features to match on is left to the vendor. Matcher need not primarily be a “minutiae matcher.” Matcher architectures in which “advanced matchers” are selectively invoked (depending upon initial screening results for that probe) are allowed. Thus, the vendor might decide to invoke (call) computationally intensive matchers only for those comparisons which show initial good results.

However, the vendor must decide if the additional features (if any) required are to be extracted and stored on disk memory during the enrollment phase. Since it may not be possible to keep all gallery images in memory, it might be necessary for the software to retrieve the data from disk during searches. This extra fetch time will be included in execution time measurements.

The vendor shall supply an absolute similarity score (“matching score”) for each candidate on the output list. In addition, the vendor should supply their estimate of the probability that a candidate is a correct match. This number should be supplied as a number between zero and 100. The number 100 will be interpreted as an extremely high confidence “hit.” This probability should be a good predictor of whether a candidate would require human examination in an operational system; a low probability candidate would presumably not be examined.

1. The vendor shall return a final output candidate list. For simplicity we recommend this list be fixed at 50 candidates.
2. The list should be sorted so as to place the most promising candidate in the number one position.
3. If minutiae are used by the matcher NIST requests that the implementation provide the number of minutiae extracted from each latent image searched.
4. If the vendor has a latent image quality measurement capability, NIST recommends that its value be supplied for each latent image searched.